Air Movement Systems

Introduction

This lesson presents the basic concepts of air movement systems and discusses, in general, how to inspect fans and ventilation systems. The ventilation system and fans are important components of an air pollution control system.

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Unlike the inspection procedures presented for control devices (Lessons 4 through 10), the fan and ventilation system inspections are not characterized by levels. However, fan data are required for all inspections that are Level 2 or higher.

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Air Movement Systems

Air movement systems consist primarily of ventilation systems and fans. The ventilation system, which includes the hoods and the ductwork leading to the control device, collects contaminants and concentrates them into one area. Fans move those collected contaminants through the control system.

Ventilation Systems

The ventilation system is comprised of hoods, which collect the pollutants, and of ductwork, which leads from the pollutant source to the air pollution control device. The capture efficiency of the hoods is important in determining the overall efficiency of an air pollution control system.

The capture efficiency of the hoods helps determine the overall efficiency of the control equipment.

> **Example:** If a poorly designed hood captures only 70% of the generated emissions, then the overall efficiency of the control system can never be greater than 70%, even if the control device is 100% efficient.

Pollutants can usually be captured effectively with an appropriately sized hood and with a fan that has enough power to pull the gas through the device. Hoods are designed to achieve the maximum pollutant capture efficiency with a minimum of airflow and power consumption.

How Are Hoods Classified?

Hoods are classified according to their shape and the manner in which they capture the contaminant. Some common hood designs are **slot, flanged slot, plain opening, flanged opening, booth,** and **canopy** (Figure 3-1).

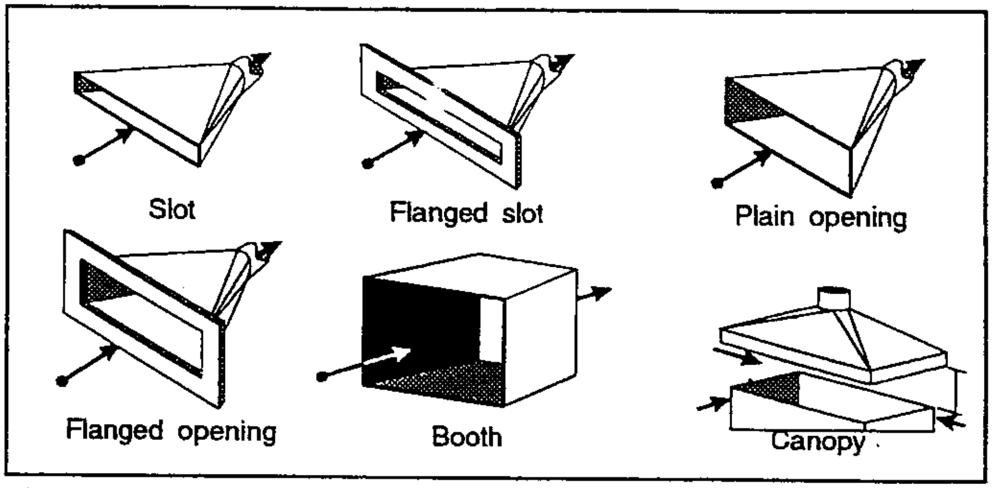

Figure 3-1. Hood Types

H..ods are classified as either enclosure or nonenclosure.

Hoods are also referred to as enclosure or nonenclosure, depending on the manner in which they capture the pollutant. Enclosure hoods completely or partially enclose the point of emissions so that capture occurs before the contaminant has a chance to disperse.

> **Example:** In many paint-spraying operations, a booth is used to capture the generated emissions. The painting can be done inside the booth or in front of it.

Nonenclosure hoods are usually located around the perimeter of the contaminant-generating source. The most common nonenclosure hood used to capture gaseous emissions is the **lip exhaust**, located on open-surface tanks (Figure 3-2).

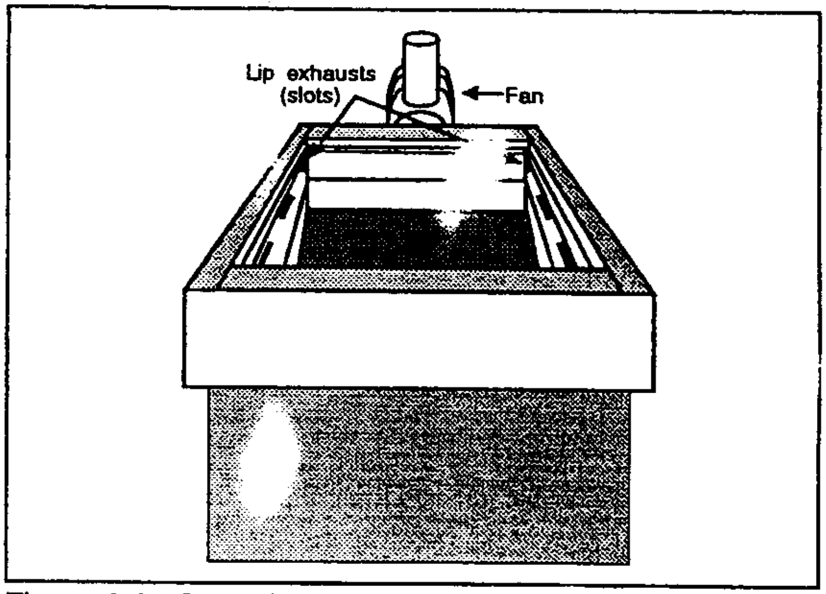

Figure 3-2. Open-Surface Tank With L.. Exhaust

Ventilation System Inspections

Ventilation system inspections involve observing the physical condition of the hoods and ductwork. If measurement ports are available, static pressure, gas temperature, and O_2 content (for combustion sources) should be measured as well. These last three parameters are measured to develop pressure, temperature, and O_2 profiles along the duct system. Table 3-1 lists the major ventilation system inspection points. The inspector should be careful around hoods, fans, and ductwork because these devices might be hot and/or electrically charged.

Ventilation system inspections include taking static pressure, gas temperature, and O_2 measurements.

Table 3-1. Ventilation System Inspection Points

Hoods

- Check for damage to the hood structure.
- Check to see that the hood has not been moved away from the pollutant source.
- Check damper positions to ensure that gas flow is not being restricted.
- Visually assess the adequacy of pollutant capture; check to see if cross drafts are affecting capture.

Ductwork

- To the extent possible, conduct a visual inspection for holes (particularly at elbows or turns) caused by erosion or corrosion.
- If data are available for measurement taps or ports along the ductwork, plot static pressure, gas temperature, and O_2 content (combustion sources only) to determine the integrity of the system.

What Type Of Damage Should The Inspector Look For?

Hoods should be inspected to determine if they have been damaged by overhead cranes or other moving equipment. Also, plant personnel might have moved a hood to gain better access to the process equipment or might have adjusted dampers controlling the gas flow.

Improper hood location or damper position will result in reduced capture efficiency. The inspector should check to see whether cross drafts are affecting capture ability. In some cases, it is possible to evaluate hoods by using static pressure readings taken one to three duct diameters downstream from the hood.

A damaged hood or damper results in reduced capture efficiency.

Ductwork abrasion normally occurs at elbows and other places where the gas stream sharply shifts direction.

The ductwork should be inspected for holes (caused by erosion or corrosion) that will induce air inleakage. Particulate matter-laden gas streams moving at high velocities (3,500 to 5,000 [illegible]min) can be quite abrasive. Abrasion normally occurs at elbows and other places where the gas stream sharply shifts direction.

Uninsulated ducts that carry hot gases are susceptible to corrosion, especially if the gas stream has high concentrations of acid vapors. Moisture on the relatively cool inner surfaces of the ducts absorbs the acidic compounds, and the resulting acidic moisture promotes corrosion. Also, any additional cooling of the gas stream, caused by air infiltration, further promotes corrosion.

How Does The Inspector Determine If Air Inleakage Exists?

Static pressure for systems with the fan located after the control device becomes more negative as one moves toward the fan.

The location of air inleakage is determined by measuring one or more parameters (static pressure, gas temperature, and/or O_2 content) at three or more points along the ductwork, and then plotting the data on a system flowchart to establish a measurement profile. The measuring points can be simple: 1/4-in. outside-diameter static pressure taps or 1- to 2-in. ports equipped with threaded caps. The points do not have to be equally spaced along the ductwork. As shown in Figure 3-3, the static pressure (on systems with the fan located after the control device) should become progressively more negative as one moves toward the fan.

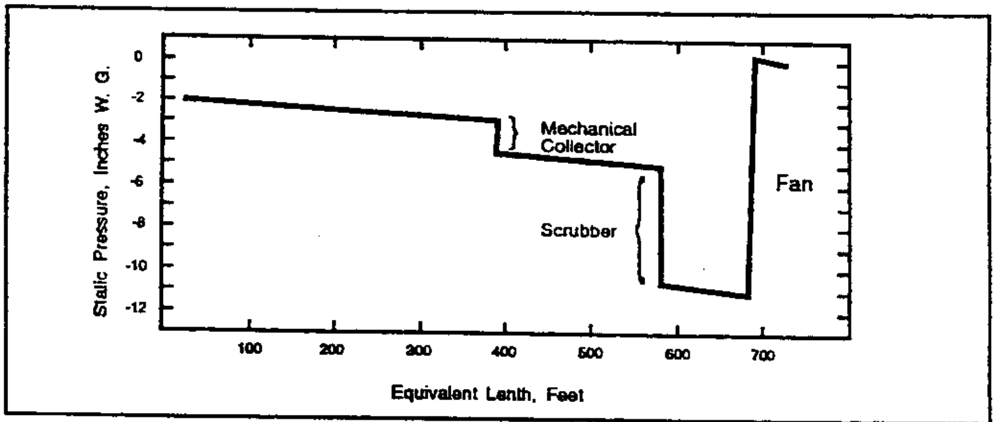

Figure 3-3. Example Static Pressure Profile Slope (System With Mechanical Collector And Wet Scrubber)

A sharp change in the static pressure profile slope that cannot be attributed to the presence of an air pollution control device suggests either p[illegible] blockage of the duct or a large air infiltration point (such as a [illegible]le, a [illegible] failure, or an open cleanout trap door).

Air infiltration should also be apparent on the gas temperature profile, because gas temperatures from combustion sources or other hot processes should decrease as the gas moves farther from the process (Figure 3-4). In negative pressure systems, a point of discontinuity in the gas temperature profile line indicates the general location of air inleakage.

Oxygen content measurements can also help spot air inleakage. The flue-gas-O_2 content should not change substantially. However, most systems have some degree of air infiltration, and while this normally leads to an increasing O_2 level as one moves away from the combustion process (Figure 3-4), a **sharp** increase in flue-gas-O_2 content indicates air inleakage.

Sharp increases in flue-gas-O_2 content indicate air inleakage.

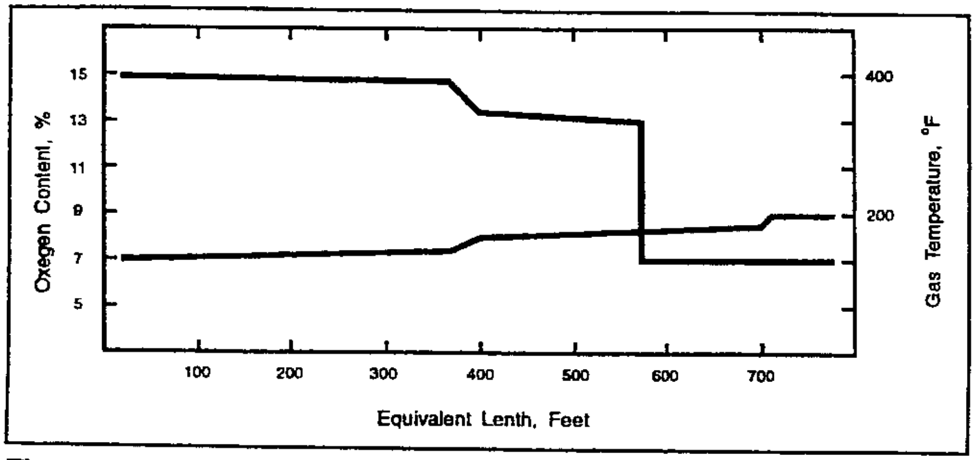

Figure 3-4. Example O_2 Content And Temperature Profiles

Fans

Fans provide the energy needed to move the contaminants from their point of collection or generation to the control device. Fans are classified as **axial** or **centrifugal**, depending on the direction of airflow through the **impeller** (a rotating device used to force a gas in a given direction).

In axial-flow fans, air moves along the axis of rotation of the fan blades (Figure 3-5).

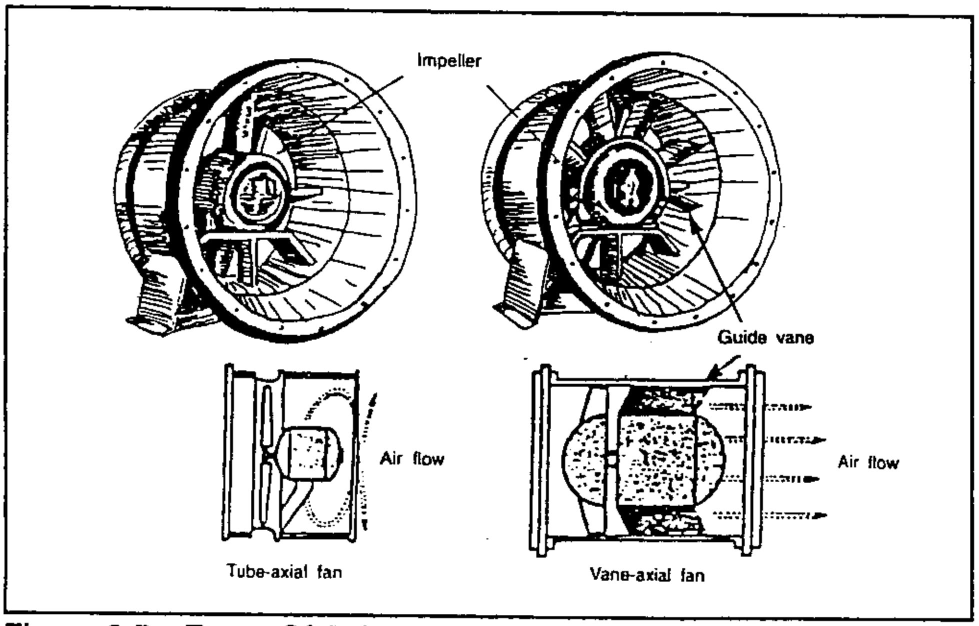

Figure 3-5. Types Of Axial Fans

Example: A home window fan or room fan is an example of an axial-flow fan.

For industrial use, axial fans are best suited for moving large volumes of clean, noncombustible air with low static pressures.

Centrifugal fans are more widely used in industry than are axial fans.

In centrifugal fans, the air enters the center of a revolving wheel or rotor and exits at right angles to the air inlet; i.e., the air usually goes in the same direction as the rotation of the blades (Figure 3-6). Centrifugal fans are more widely used in industry than are axial fans because centrigual fans can handle dirtier airstreams at higher static pressures.

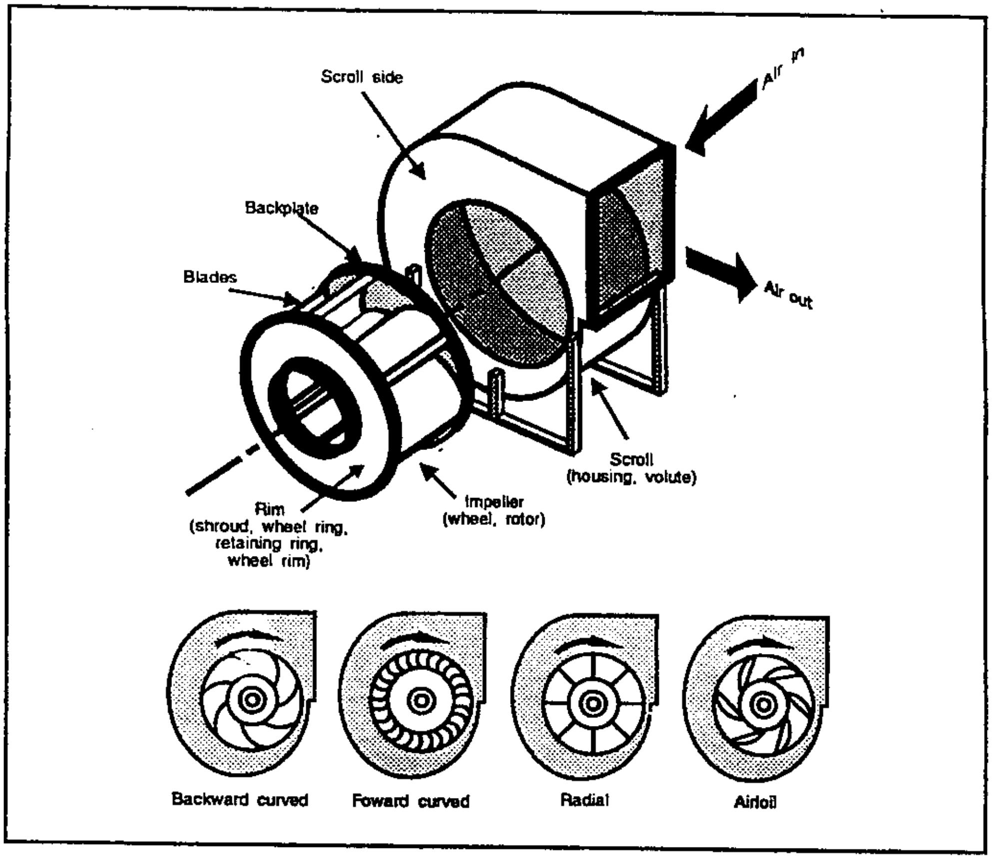

Figure 3-6. Types Of Centrifugal Fans

Fan Inspections

Fan inspections require little time and provide very valuable diagnostic information. The inspection points described on the following pages are useful for relatively small direct- and belt-drive fans with gas flow rates of less than 50,000 actual cubic feet per minute (acfm). Larger, more complex systems can be evaluated using information available in standard texts, such as *Fan Engineering* (Buffalo Force, 1980).

Physical Condition of Fan Housing. The fan should be observed to determine if it is vibrating. In certain very unusual circumstances, vibration can be so severe that the fan could disintegrate. In such cases, the inspection should be halted immediately, and plant management should be informed of the fan's condition.

Check for fan vibration.

Most small fans have flexible sleeves on the inlet and outlet ducts. These sleeves reduce transmission of normal fan vibration to the ductwork and also provide for thermal expansion. Cracks and tears in these sleeves are common; if these occur on the inlet side, cold ambient air is drawn in, reducing the quantity of gas pulled through the process hoods. This might, ultimately, cause increased fugitive emissions.

Check flexible sleeves for cracks or tears.

If the process uses an automatic controller to adjust ventilation air flow rate, then the fan will compensate by drawing more total airflow (air inleakage plus air from the process hood) to maintain the desired airflow from the process, thereby causing the fan to use more energy.

Corrosion on the outside of the housing might indicate that gas temperatures are below the acid vapor and/or water vapor dew points. If this problem exists, the ductwork leading to the fan from the control device will also corrode, resulting in significant air inleakage. Inleakage is easily identified by a lower-than-expected gas temperature coupled with a higher-than-normal flue-gas-O_2 content (combustion sources only). The O_2 content can be measured with O_2 analyzers, most of which are relatively easy to use and are reasonably accurate ($\pm 1\%$ O_2). Plant personnel should also routinely inspect the fan wheel for erosion, corrosion, and/or material accumulation.

Fan Operating Conditions. The most important operating parameter for a fan is its rotational speed, measured in revolutions per minute (rpm). The gas flow rate through a given system is directly proportional to the rpm—the higher the rpm, the higher the gas flow rate. The rpm of direct-drive fans does not vary, and a rough estimate of the rpm for belt-driven fans can be obtained by multiplying the fan motor rpm by the ratio of the motor and fan sheave diameters (Equation 3-1 and Figure 3.7).

Rotational speed is the most important fan operating parameter.

$$\text{Fan rpm} = \text{motor rpm} \times \frac{\text{motor sheave diameter}}{\text{fan sheave diameter}} \qquad (3\text{-}1)$$

Obviously, sheave measurements are subject to some error because they must be done by looking through a belt guard. **(Caution: The belt guard should not be removed to obtain a more accurate measurement.)** Belt slippage can also lead to a rotational speed several hundred rpm lower than estimated. This slippage is usually detectable by an audible squealing and, in extreme cases, poor belt tension.

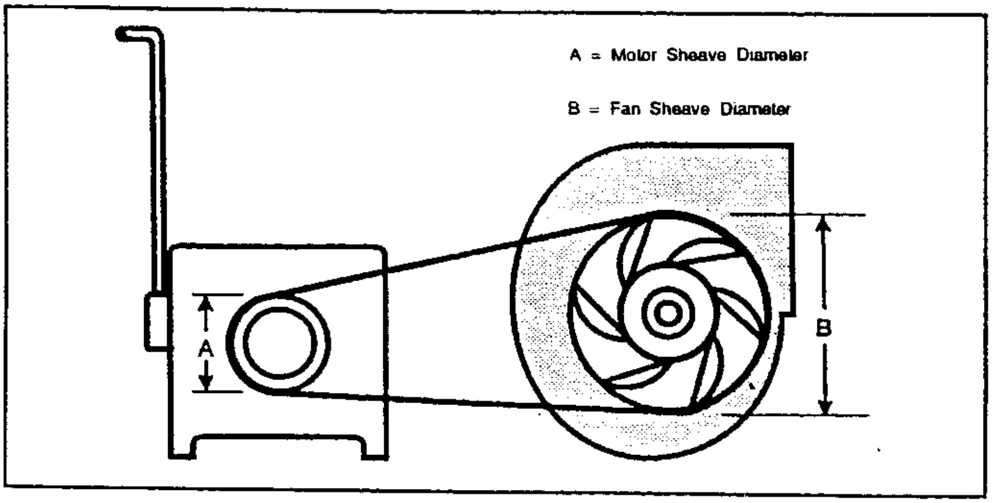

Figure 3-7. Determining Belt-Driven Fan RPM

Rotational speed can be measured b. using various types of tachometers.

A more accurate measurement of fan rpm can be made using either a manual **tachometer**, a **phototachometer**, or a **strobe-type tachometer**. Using a manual tachometer is very straightforward if there is a convenient access port to the fan shaft. However, the configuration of the belt guard often precludes the use of a manual tachometer. In such cases, a phototachometer, which senses and counts pulses of reflected light, might be used.

The most accurate readings are obtained if the instrument manufacturer has affixed a piece of reflective tape on the fan shaft. It is possible to read integer multiples of the rpm if there is more than one reflective site within the field of view of the sensor. The rough estimate derived by the sheave ratio is generally useful in confirming that the lowest reading is, in fact, the actual rotational speed.

The rotational speed of simple fans **cannot** increase unless plant personr replace either the motor or the sheaves. Because an increase in r normally results in a higher gas flow rate, such an increase can adver affect the performance of certain types of mechanical collectors, ESPs, fabric filters. If the tip speed exceeds permissible limits (specified by the manufacturer), the fan might disintegrate.

Gas flow is directly pr- -rtional to rotational speed.

For most fans used with air pollution control systems, the total horsepower required (**brake horsepower**) increases as the gas flow rate increases. If the brake horsepower could be accurately calculated based on simple measurements of fan operating conditions, a reasonable e -nate could be made of the gas flow rate through the system. Unfort ly, brake horsepower also depends on the power factor, which is n ier easy to measure nor constant. The relationship between brake l se-power and motor operating parameters is shown below (Equation 3-_):

$$\text{Fan brake horsepower} = \underset{\text{(amps)}}{\text{current}} \times \underset{\text{(volts)}}{\text{voltage}} \times \underset{\text{factor}}{\text{power}} \times 0.746 \qquad (3\text{-}2)$$

Because of the direct relationship between the motor current, the brake horsepower, and the basic nature of the fan curves, it is possible to identify significant changes in the gas flow rate using only the fan motor current, which is relatively easy to measure using an **inductance ammeter**. Normally, an electrical cabinet must be opened to reach wire not covered by conduit piping. If the motor is a three-phase type, the current in all three wires should be measured, and the average current should be computed. **(Caution: Because of potential shock hazards, inspectors should never open electrical cabinets. The plant electrician should make all such measurements.)** Usually, the motor horsepower is used in fan performance evaluations. Table 3-2 summarizes the fan inspection points.

Caution: Because of potential shock hazards, inspectors should never open electrical cabinets. The plant electrician should make all such measurements.

Table 3-2. Fan Inspection Points

Housing

- Inspect for vibration; **terminate inspection and leave the area immediately if severe fan vibration is evident.**
- Check flexible sleeves on inlet and outlet ducts for tears or cracks.
- Check for exterior corrosion.

Operating Conditions

- Calculate fan rpm using motor sheave and fan sheave ratios and compare to baseline values.
- Calculate motor current (corrected to standard conditions) and compare to baseline value; a shift of over 20% from baseline indicates a probable significant change in the gas flow rate.

Because the brake horsepower is also a function of gas temperature, the measured motor current must be adjusted for standard conditions before being compared with the baseline motor current. This conversion can be conducted by using Equation 3-3 below with the data presented in Table 3-3.

$$\text{Motor current (@ STP)} = \text{motor current (@ the motor's temp)} \times \text{(Table 3-3 power factor @ the motor's temp)} \qquad (3\text{-}3)$$

Table 3-3. Fan Data Temperature Correction[a]

Temperature (°F)	Power Factor	Temperature (°F)	Power Factor
20	0.91	320	1.47
40	0.94	340	1.51
60	0.98	360	1.55
80	1.02	380	1.59
100	1.06	400	1.62
120	1.09	420	1.66
140	1.13	440	1.70
160	1.17	460	1.74
180	1.21	480	1.77
200	1.25	500	1.81
220	1.28	520	1.85
240	1.32	540	1.89
260	1.36	560	1.92
280	1.40	580	1.96
300	1.43	600	2.00

[a]From "Basic Energy/Environment Analysis," NAPA information series 67, by C. Heath, August 1978.

If the corrected motor current has shifted more than 20%, the gas flow rate has probably changed significantly.

If the corrected motor current has shifted more than 20% from the baseline actual prevailing gas flow rate can be measured using EPA Reference Method 2 procedures.

Summary

The air movement system is an integral part of an air pollution control system. The ventilation hoods and ductwork capture contaminants, and the fans push or pull those contaminants through the control device.

Ventilation system inspections involve observing the physical condition of the hoods and ductwork. Fans should be checked to determine the physical condition of the fans' housings and the fans' rotational speeds.

Review Exercises

1. If a canopy hood has a capture efficiency of 80%, the overall efficiency of the air pollution control system cannot be:

   a. Less than 80%
   b. Greater than 80%

2. Some common hood shapes are:

   a. Canopy
   b. Axial
   c. Slot
   d. Booth
   e. All of the above
   f. a, c, and d only

3. True or false? Inspection of the ventilation system includes both visual inspections for holes or damage and plots of gas temperature, static pressure, and (sometimes) flue-gas-O_2 content.

4. If the fan is located after the air pollution control device, the static pressure plot should:

   a. Show static pressure steadily becoming less negative with measurements taken closer to the fan.
   b. Remain essentially level.
   c. Reflect sharp changes in pressure depending on the direction of the ductwork.
   d. Become progressively more negative with measurements taken closer to the fan.

5. True or false? A sharp change in either the static pressure profile or the gas temperature profile might indicate a source of air inleakage.

6. Abrasion in a ductwork system occurs most commonly:

   a. Just before the control device.
   b. Just after the capture point.
   c. At elbows or other points where there are sharp changes in gas flow direction.
   d. Where gas flow is very slow.

7. The two general classifications of fans are:

   a. Centrifugal and axial.
   b. Controlled-rotation and free-rotation.

8. The first step in the fan inspection is to:

   a. Inspect the flexible sleeves.
   b. Calculate the fan rpm.
   c. Determine the gas temperature entering the fan.
   d. Inspect the physical condition of the fan housing.

9. Multiplying the fan motor rpm times the ratio of the motor and fan sheaves will give a rough estimate of:

   a. The physical condition of the fan.
   b. The fan rpm for belt-driven fans.
   c. The brake horsepower.
   d. None of the above.

10. True or false? Significant changes in gas flow rates typically must be identified using the brake horsepower calculation, which is relatively simple.

11. The fan motor current must be adjusted to ______________ before being compared with the baseline value.

12. A shift of ______________ in the corrected fan motor current from the baseline value probably indicates a significant change in the gas flow rate through the air pollution control system.

   a. More than 20%
   b. Less than 15%
   c. At least 35%
   d. Exactly 25%

Answers

1. b. Greater than 80%

2. f. a. Canopy
   c. Slot, and
   d. Booth

3. True

4. d. Become progressively more negative with measurements taken closer to the fan.

5. True

6. c. At elbows or other points where there are sharp changes in gas flow direction.

7. a. Centrifugal and axial

8. d. Inspect the physical condition of the fan housing.

9. b. The fan rpm for belt-driven fans.

10. False. Significant changes in gas flow rates are more easily measured by the fan motor current using an inductance ammeter.

11. standard conditions

12. a. More than 20%